PALEONTOLOGY.—*Morphology of the test in the foraminiferal genus* Tristix *Macfadyen.* ALFRED R. LOEBLICH, JR., and HELEN TAPPAN, U. S. National Museum.

During the course of many years' work on the Mesozoic Foraminifera in America, the writers have encountered numerous specimens of the genus *Tristix* Macfadyen. In almost every occurrence, both in America and elsewhere, the species of this genus are accompanied by specimens like the form described as *Quadratina* by ten Dam (1946, p. 65). Although in the past the writers have differentiated these two morphological types, *Tristix* being triangular in section and *Quadratina* quadrate in cross section, the evidence now seems to indicate definitely that they are congeneric, and the name *Quadratina* ten Dam should be suppressed as a junior synonym of *Trixtix* Macfadyen.

Duplication of species.—In any large series of *Tristix*, selected from a single sample there are invariably a few quadrate forms that can be associated with the typical specimens by a similarity in all other characters. Macfadyen (1941, p. 55) in describing the genus *Tristix* also noted that some "species" were quadrangular in section instead of triangular, and stated that these "may possibly be found to be congeneric." A study of the occurrence of described species of *Quadratina* shows that almost invariably they are associated with very closely similar species of *Tristix*, and probably one or the other of the specific names should be placed in synonomy. An example of this is shown by four Jurassic species described by the writers (1950, p. 52) from the western interior of the United States and here shown in Figs. 1–4. These specimens were originally referred to *Tristix alcima* Loeblich and Tappan (Fig. 1) and *Quadratina inornata* Loeblich and Tappan (Fig. 2), but they are similar in being comparatively large, robust and with rounded angles, and large circular apertures. The latter name is here placed in synonymy. Another pair of "species" from the same beds were *Tristix reesidei* Loeblich and Tappan (Fig. 3) and *Quadratina juncta* Loeblich and Tappan (Fig. 4), the "types" of both similarly being smaller than the preceding form, more sharply angled and with more deeply excavated sides. The last name here is also placed in synonymy. An example from the Lower Cretaceous is described later in this paper, under *Tristix quadrata* (Vieaux).

There are numerous other instances that could be cited from the American Lower Cretaceous, but a complete list of synonymies will be given by the writers in their forthcoming monograph; hence is not discussed here. A similar duplication of species can be shown for most other occurrences of *Quadratina*, as they seem always to be associated with triangular forms of close affinity.

Evidence from "freaks."—It has been often observed that occasional "monstrous" specimens may be of value in determining relationships of foraminiferal genera. Examples are specimens of *Gaudryina*, with an occasional terminal chamber showing a tendency toward *Gaudryinella* (Tappan, 1943, p. 489), and *Citharinella*, which develops a third angle, showing a relationship with *Tribrachia* (Loeblich and Tappan, 1941, p. 19). We have also in our Lower Cretaceous collections specimens of *Citharina* with an occasional equitant chamber showing a development toward *Frondicularia*, a *Lenticulina* that develops a long series of globular uniserial chambers like *Nodosaria*, *Flabellammina* developing into *Frankeina*, *Gümbelina* developing into *Rectogümbelina*, *Textularia* with a central terminal chamber or two suggesting a relationship with *Bigenerina* and many similar examples.

In the large quantity of Lower Cretaceous material examined by the writers there have been found a few such monstrosities which show some bearing on the relationships of the forms now under discussion. A specimen from the Glen Rose formation (Fig. 7) is a typical *Tristix* in its early stages, but at about the midpoint of its development it became suddenly quadrate, so that it is a *Tristix* for half of its life span and a "*Quadratina*" in its later life history. A record of a similar occurrence of a "mixed" form is found in Berthelin (1880, p. 47). He recorded *Rhabdogonium acutangulum* Reuss from the French Albian, stating:

> My specimens have chambers a little less serrated than the type, and tend to approach *R maertensi* Reuss; but do not have a quadrangular section.
>
> The triangular shells are in general somewhat more numerous than the quadrangular; but the character is not an absolutely constant one. I possess a specimen of an upper Jurassic species, which shows an abrupt passage without any transition from one to the other form. (Free translation.)

From this description Berthelin apparently had a specimen similar to the "mixed" form of Fig. 7. Obviously a single specimen cannot change its generic identity midway in its growth, and these freaks thus show a definite relationship between these "genera." Another freak in our Lower Cretaceous collection (although not here illustrated) is a *Lingulina* in its early stage, and becomes triangular in the later development. These two examples would seem to definitely indicate that *Lingulina*, *Tristix* and "*Quadratina*" should at least be placed in the same family, with *Lingulina* probably ancestral to *Tristix*.

A specimen that shows an even more interesting development is shown in Fig. 8. This is a twinned specimen which developed chambers simultaneously in opposite directions from the proloculus, one series of chambers being triangular in section (Fig. 8c) and the opposite extremity being quadrate in section (Fig. 8b). This specimen shows no transition from one genus to another but apparently it belonged to the two "genera" simultaneously and therefore supplies additional evidence that *Tristix* and *Quadratina* are synonymous, the number of angles being variable as are the number of ribs in a *Nodosaria*, etc.

Character of the aperture.—The aperture of *Tristix* presents several problems. It varies from a simple rounded one to triradiate or radiate. The genotype species of *Tristix*, *Rhabdogonium liasinum* Berthelin, has a circular aperture. Our Jurassic species also have only simple apertures (Loeblich and Tappan, 1950 a, b) as do the majority of the Lower Cretaceous species (Tappan, 1940, 1943). An occasional species which has deeply excavated sides may show a triradiate aperture, as does *Tristix excavata* (Reuss) as shown by van Voorthuysen (1947), and as can be seen on certain of our Lower Cretaceous specimens. This reaches a climax in such forms as *Triplasia temirica* Dain, 1934, which has a radiate aperture. It is possible that forms with definite radiate apertures should be excluded from this genus, but because of the fact that numerous genera of the Lagenidae may have either rounded or radiate apertures and as no specimens of this Russian Jurassic species have been available to the writers for examination, the radiate aperture is not here considered sufficiently important to warrant separation of this species.

"*Quadratina*" shows a similar variation in apertural characters. The genotype species, *Quadratina depressula* ten Dam, was described as having a radiate aperture. Other described species have simple rounded apertures. These quadrate forms are always less frequent than the triangular ones, however, hence as great a variation is not to be expected, because of the more limited number of available specimens.

Van Voorthuysen (1947, p. 44) figured a short internal tube in *Tristix excavata* Reuss from the Albian of Holland, but these could only be observed in young specimens with delicate and hollow tests. The writers have not been able to demonstrate an internal tube in the abundant specimens from the Comanchean strata (Albian) of Texas, but this may in part be due to the type of preservation and more probably, these short delicate internal tubes may have been resorbed by the organism.

Relationship of Tristix *and* Dentalinopsis.—In general *Tristix* is strongly triangular in section and *Dentalinopsis* Reuss is rounded in cross section, with three faint longitudinal keels. However, some species of *Tristix* closely approach the generic characters of *Dentalinopsis* and they seem to be closely related. This is especially true of some of the quadrate species such as *Dentalinopsis subquadrata* Tappan, 1940, which has very poorly developed angles and *Quadratina euthemon* Loeblich and Tappan which is nearly circular in section, with four faint longitudinal keels. It is possible that these species should be placed in *Dentalinopsis*, because of the lack of angularity and if so, this genus also would vary from triangular to quadrangular, presenting another character in common with *Tristix* and *Dental-*

inopsis and suggesting some relationship between them.

It is interesting to note, however, that these two genera are placed in separate families by various authors. Cushman (1948, p. 261) places *Dentalinopsis* in the family Buliminidae and derives it from the series *Angulogerina–Trifarina–Dentalinopsis* by acceleration of the uniserial stage, and *Tristix* was placed in the Lagenidae. Galloway (1933, p. 372) places *Dentalinopsis* in the family Uvigerinidae and also derives it from *Trifarina* by acceleration of the uniserial stage. Galloway notes that *Dentalinopsis* may have had some other ancestry as such uniserial forms are produced in many lines of evolution and also noted that *Dentalinopsis* occurs much earlier in the geologic column than does *Trifarina*, which was not mentioned by Cushman. Van Voorthuysen (1947, p. 45) also derives *Dentalinopsis* from *Trifarina* and has the line *Tristix–Entosolenia* [=*Oolina*] derived from an offshoot of the line *Trifarina–Dentalinopsis*. The derivation of *Oolina* (*Entosolenia* of van Voorthuysen) from *Tristix* is untenable in the writers' opinion, as we strongly doubt that unilocular forms are invariably the evolutionary end members, derived from multilocular ancestors, although this has been often stated in the literature. *Oolina* occurs as low stratigraphically as the Albian in Texas and the Upper Lias of Switzerland and if earlier records of *Lagena* were critically examined it may be found that some true *Oolina* occurred in earlier strata.

The presence of the internal tube in *Tristix* has led to its being placed by van Voorthuysen in the family Buliminidae, but it seems more difficult to see why *Dentalinopsis*, which appears so closely related to the Lagenidae, and incidentally to *Tristix*, is placed in the Buliminidae, for no internal tube has been demonstrated in *Dentalinopsis*. At the present time, the writers are uncertain as to what value in classification should be placed on these internal tubes. Parr (1947, p. 128) has included *Oolina* (*Entosolenia*), *Fissurina*, and *Parafissurina* in the family Lagenidae although all possess clearly defined internal tubes. Some other lagenids, such as *Lingulina falcata* Heron-Allen and Earland, possess internal tubes. *Glandulina glans* d'Orbigny of the Polymorphinidae has been demonstrated to possess an internal tube by Selli (1947, pl. 3) and *G. laevigata* d'Orbigny also has been shown to have this identical structure by van Voorthuysen (1950, p. 37). These tubes have been observed by the present writers in *Glandulina* from as far back as the Eocene.

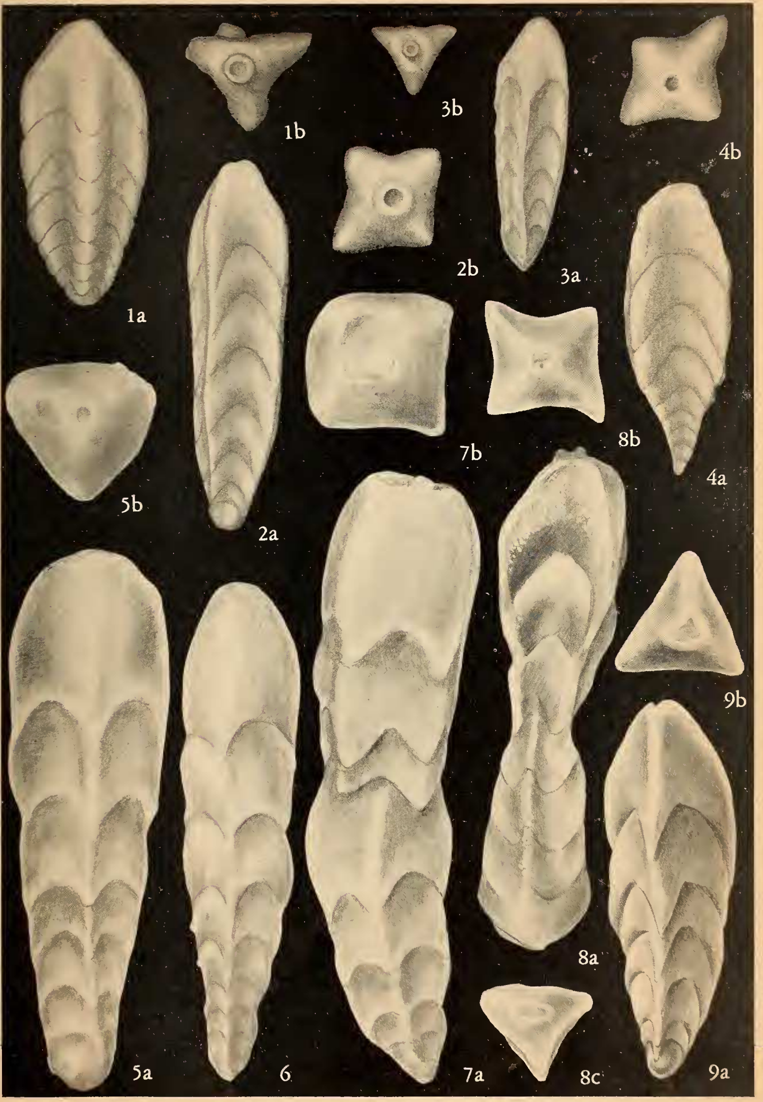
Figs. 1a–2b.—*Tristix alcima* Loeblich and Tappan: 1a, Side view of triangular holotype (USNM 105007); 1b, top view, showing subacute angles and rounded aperture; 2a, side view of quadrate form (USNM 105013) originally described and named as *Quadratina inornata* Loeblich and Tappan; 2b, top view, showing quadrate section, subacute angles, and rounded aperture. All × 95 and both specimens from the Redwater shale member of the Sundance formation (Oxfordian) of South Dakota.

Figs. 3a–4b.—*Tristix reesidei* Loeblich and Tappan: 3a, Side view of holotype (USNM 105009) showing arched sutures, acute angles, and pointed base; 3b, top view, showing triangular section, acute angles, and rounded aperture × 95; 4a, side view of quadrate form (USNM 105017) showing pointed base and moderately excavated sides (this form was originally described as *Quadratina juncta* Loeblich and Tappan); 4b, top view, showing quadrate section and rounded aperture. All × 158 and both specimens from the Redwater shale member of the Sundance formation (Oxfordian) of South Dakota.

Figs. 5a–7b.—*Tristix comalensis* Loeblich and Tappan, n.sp.: 5a, Side view of holotype (USNM P. 842) showing arched sutures, triangular form with little excavation of the sides; 5b, top view showing triangular form with rounded angles and rounded aperture; 6, side view of paratype (USNM P. 843a) showing more slender form than that of the holotype; 7a, side view of paratype (USNM P. 843b) showing form with early *Tristix*-stage and later stages developing a quadrate section ("*Quadratina*" stage) thus producing a "mixed" form; 7b, top view showing quadrate outline of late chambers of the "mixed" form. All × 150 and all from the Glen Rose formation, Trinity group, Lower Cretaceous of Comal County, Tex.

Figs. 8a–9b.—*Tristix quadrata* (Vieaux): 8a, Side view of twinned hypotype (USNM P. 845) with the quadrate half oriented at the top of the figure and the lower half exhibiting the triangular section, both parts arising from the same proloculus; 8b, top view of "*Quadratina*" half showing rounded aperture and slightly excavated sides; 8c, top view of *Tristix* portion of the twin showing elongate aperture (from the Kiamichi formation, Fredericksburg group, Lower Cretaceous, of Tarrant County, Tex.); 9a, side view of typical triangular hypotype (USNM P. 846) showing rounded proloculus and arched sutures; 9b, top view showing rounded aperture and sides with little excavation (from the Kiamichi formation, Fredericksburg group, Lower Cretaceous, of Johnston County, Okla.). All × 150.

All illustrations are shaded camera-ludica drawings. Figs. 1–4 by Helen Tappan Loeblich; Figs. 5–9 by Sally D. Lee, scientific illustrator, Smithsonian Institution.



FIGS. 1–9. (See opposite page for legend).

Other members of the Polymorphinidae such as *Polymorphina williamsoni* Heron-Allen and Earland, *P. acuta* Roemer and *P. soria* Reuss also have well-defined internal tubes. In addition the writers have in preparation the description of a Recent fauna in which many of the Polymorphinidae have internal tubes. It seems that this character appears in widely divergent families in the Foraminifera and may be considerably more prevalent than is noted in the literature. The writers hesitate to remove from the Polymorphinidae the species that possess internal tubes, until the whole group is studied in detail, and it seems best to consider both *Dentalinopsis* and *Tristix* as members of the family Lagenidae, closely related to each other and to *Lingulina*, and although all three appear early in the history of the family, the last two appear to be somewhat specialized in that at least some of their species possess well-defined internal tubes.

With the above considerations in view concerning the form of the test the writers consider it advisable to suppress the name *Quadratina* as a junior synonym of *Tristix* and to revise the generic description of *Tristix* so as to include quadrate as well as triangular forms.

Genus **Tristix** Macfadyen, 1941

Tristix Macfadyen, Phil. Trans. Roy. Soc. London, ser. B, biol. sci., no. 576, **231**: 54. 1941.
Tricarinella ten Dam and Schijfsma. C. R. Somm. Soc. Geol. France, no. 16: 233. 1945.
Quadratina ten Dam, Bull. Soc. Géol. France, ser. 5, **16**: 65. 1946.
Dentalinopsis Reuss (part, of authors)
Rhabdogonium Reuss (part, of authors)
Triplasia Reuss (part, of authors)

Emended diagnosis.—Test free, uniserial, generally triangular in section, but occasionally quadrate; wall calcareous, hyaline; aperture terminal, rounded to radiate, with an internal tube in at least some species.

Tristix comalensis Loeblich and Tappan, n. sp
Figs. 5–7

Test free, narrow elongate, slightly tapering, sides nearly flat, angles broadly rounded; chambers up to 9 in number, increasing gradually in height as added, final chamber of approximately equal height and breadth; usually triangular in section, and infrequently quadrate; sutures distinct, slightly depressed, gently arched at the center of each face of the test, curving gently downward to the angles of the test; wall calcareous, hyaline, surface unornamented; aperture terminal, rounded.

Length of holotype (Fig. 5), 0.65 mm; greatest breadth, 0.18 mm; length of paratype of Fig. 6, 0.60 mm; breadth, 0.15 mm. Length of paratype of Fig. 7, 0.73 mm. Other specimens range from 0.26 to 0.99 mm in length.

Remarks.—This species differs from *T. quadrata* (Vieaux) in being larger and broader with higher chambers and less strongly arched sutures, more rounded angles and less excavated sides.

Types and occurrence.—Holotype (USNM P. 842) and paratypes of Figs. 6, 7 (USNM P. 843a–b) and unfigured paratypes (USNM P. 844a–v) all from the Glen Rose formation (Trinity group), Lower Cretaceous, from 520 feet below the top of the formation, in a road cut on the east side of U. S. Highway 281, 2.4 miles north of the junction with Texas Highway 46, in Comal County, Tex.; collected by A. R. Loeblich, Jr., 1949.

Tristix quadrata (Vieaux)

Dentilinopsis excavata (Reuss) Plummer (not *Rhabdogonium excavatum* Reuss, 1862), Univ. Texas Bull. 3101: 187, pl. 9, figs. 11–12. 1931.
Dentalinopsis excavata (Reuss) Tappan, Journ. Pal. **14** (2): 118, pl. 18, figs. 10 a–b. 1940.
Dentalinopsis märtensi (Reuss) Tappan (not *Rhabdogonium märtensi* Reuss, 1863), Journ. Pal. **14** (2): 119, pl. 18, figs. 11 a–c. 1940; Journ. Pal. **17** (5): p. 509, pl. 81, figs. 23 a–b. 1943.
Dentalinopsis quadrata Vieaux, Journ. Pal. **15** (6): 626, pl. 85, figs. 8 a–b. 1941.
Tristix acutangula (Reuss) Loeblich and Tappan (not *Rhabdogonium acutangulum* Reuss, 1863), Woodbine Symposium, Southern Methodist Univ., Fondren Sci. Ser. no. 4: 88, pl. 2, figs. 17–18. 1951.

Test free, small, narrow, parallel-sided; consisting of a rectilinear series of about 3 to 9 chambers, increasing gradually in height as added and either triangular or quadrangular in section, with angles fairly sharp and sides moderately excavated; sutures distinct, slightly depressed, strongly arched on the faces, extending sharply downward at the angles; wall calcareous, hyaline; aperture terminal, rounded.

Length from 0.3 to about 0.7 mm, breadth of a face 0.13 to 0.18 mm.

Remarks.—This species has been referred to various European species in the past, but the European species are distinct. *Rhabdogonium excavatum* Reuss is a much larger species, with flaring rather than parallel sides and with much more deeply excavated faces. *R. märtensi* Reuss is a quadrangular form with sharper angles and more excavated sides and is much larger (the type being 1.15 mm in length) and more flaring. *R. acutangulum* Reuss differs in being larger, with much lower chambers, which are only very slightly arched centrally.

The only available name proposed for the present species is *Dentalinopsis quadrata* Vieaux. This specific name was proposed for the quadrate forms, but must be applied to the entire species, even though it is actually descriptive of only a small percentage of the specimens, the majority being triangular in section.

The holotype of Vieaux was stated to be in the University of Oklahoma collections, but Vieaux's types have never been received at that institution and are thus not available for comparison. However, the present writers were on the collecting trip with Vieaux when his samples were obtained, and a duplicate set of all samples is in our collection. These samples have supplied many specimens of both the triangular forms, which Vieaux referred in his faunal list to *Dentalinopsis excavata* (Reuss), and the quadrangular forms on which he based his species *D. quadrata*. The specimens referred by Tappan (1943, p. 509) to *D. quadrata* are a distinct species, a much larger form than the present species, and with more excavated sides.

Types and occurrence.—Holotype (in Vieaux collection) from the Denton formation of north Texas.

Hypotype of Fig. 8 (USNM P. 845) from the Kiamichi formation, from a 5-foot section of brown marl, 11 feet above the base of the exposure in a deep road cut on the Stove Foundry Road, just north of the new Texas and Pacific Railroad shops, in Fort Worth, Tarrant County, Tex. Collected by A. R. Loeblich, Jr., and Helen Tappan Loeblich, 1941.

Hypotype of Fig. 9 (USNM P. 846) from the Kiamichi formation, from a 4.2-foot section of dark blue-gray clay shale with sandy seams, in a zone of abundant *Gryphea navia* 3 feet above the base of the exposure and 15 feet below the base of the Duck Creek, in a deep roadside ditch on the south side of the road in the SE$\frac{1}{4}$, sec. 10, T. 5 S., R. 7 E., 1 mile east of Bee, Johnston County, Okla. Collected by W. E. Ham, of the Oklahoma Geological Survey, and A. R. Loeblich, Jr., 1946.

Other published records figure this species from the Del Rio clay of central Texas, the Grayson and Duck Creek formations of northern Texas and southern Oklahoma, and the Maness formation (subsurface) of east Texas. It thus ranges from the Kiamichi formation (Fredericksburg) through the Maness formation (uppermost Washita).

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